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Oxygen isotope geochemistry of mafic phenocrysts in primitive mafic lavas from the southernmost Cascade Range, California

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Abstract

Previously reported whole-rock $\delta^{18}O$ values (5.6–7.8‰) for primitive quaternary mafic lavas from the southernmost Cascades (SMC) are often elevated (up to 1‰) relative to $\delta^{18}O$ values expected for mafic magmas in equilibrium with mantle peridotite. Olivine, clinopyroxene, and plagioclase crystals were separated from 29 geochemically well-characterized mafic lavas for $\delta^{18}O$ measurements by laser fluorination to assess modification of the mantle sources by ancient and modern subducted components. Oxygen isotope values of olivine phenocrysts in calc-alkaline lavas and contemporaneous high alumina olivine tholeiitic (HAOT) lavas generally exceed depleted mantle olivine values (~4.9–5.3‰). Modern addition of up to 6 wt% slab-derived fluid from Gorda serpentinized peridotite dehydration (~15‰) or chlorite dehydration (~10‰) within the serpentinized peridotite can provide the ^{18}O enrichment detected in olivine phenocrysts ($\delta^{18}O_{olivine}$ = 5.3–6.3‰) in calc-alkaline mafic lavas, and elevate ^{18}O in overlying mantle lithosphere, as well. Specifically, although HAOT $\delta^{18}O_{olivine}$ values (5.5–5.7‰) may reflect partial melting in heterogeneous ^{18}O enriched mantle source domains that developed during multiple subduction events associated with terrane accretion (e.g., <1 wt% of ~15‰ materials), an additional ^{18}O enrichment of up to 2 wt% of 10–15‰ slab-derived hydrous fluids might be accommodated. The calc-alkaline primitive magmas appear to have experienced a continuous range of open system processes, which operate in the mantle and during rapid magma ascent to eruption, and occasionally post quench. Textural relationships and geochemistry of these lava samples are consistent with blends of mafic phenocrysts and degassed melts in varying states of ^{18}O disequilibrium. In lenses of accumulated melt within peridotite near the base of the crust, coexisting olivine and clinopyroxene $\delta^{18}O$ values probably are not at isotopic equilibrium because fluids introduced into the system perturbed the $\delta^{18}O_{melt}$ values. A "sudden" melt extraction event interrupts ^{18}O equilibration in phenocrysts and poorly mixed melt(s). Rapid ascent of volatile oversaturated primitive mafic magma through the crust appears to be accompanied by devolatilization and crystallization of anorthite-rich plagioclase with elevated $\delta^{18}O_{plag}$ values. The $(Sr/P)_N$ values for the whole rock geochemistry are consistent with a $^{87}Sr/^{86}Sr$ ~0.7027 slab-derived fluid addition into the infertile peridotite source of magmas, and melt devolatilization is recorded in the mixture of disequilibrium $\delta^{18}O$ values for the constituent phases of lavas. Morbidity of the Gorda Plate as it undergoes intense deformation from the spreading ridge to the trench is likely a key factor to developing the carrying capacity of hydrous fluids and mineral phases in the slab subducting into the SMC mantle.

Keywords: Southernmost Cascade Range, primitive mafic lavas, oxygen isotopes, phenocrysts, laser fluorination, slab-derived hydrous fluids, magma devolatilization